GEOSPATIAL VIDEO MONITORING OF NEARSHORE BENTHIC HABITATS OF BISCAYNE BAY, FLORIDA USING THE SHALLOW-WATER POSITIONING SYSTEM (SWaPS)

DIEGO LIRMAN[1]
GREGORY DEANGELO[2]
ALEXANDRA BROWN[3]

1. Corresponding author
   University of Miami
   Rosenstiel School of Marine and Atmospheric Science
   4600 Rickenbacker Cswy
   Miami, FL 33149
   dlirman@rsmas.miami.edu

2. NOAA/National Geodetic Survey
   1315 East-West Hwy
   Silver Spring, MD 20910
   Gregory.L.Deangelo@noaa.gov

3. University of Miami
   Department of Marine Science
   Coral Gables, FL 33124
   lexiebrownie@hotmail.com

Running Head: Geospatial Video Suveys of Benthic Marine Communities

ABSTRACT

The nearshore habitats of Biscayne Bay, a shallow lagoon adjacent to the city of Miami, are heavily influenced by salinity fluctuations caused by freshwater discharges from canals but the benthic communities in these susceptible littoral habitats have been under-represented in existing monitoring programs due to the difficulties associated with boat access. In this project, we implemented a geospatial video survey technique, the Shallow-Water Positioning System (SWaPS), to monitor the abundance and distribution of benthic organisms in western Biscayne Bay. This system uses a GPS receiver attached to a video camera installed in a shallow-draft boat and each video frame recorded is stamped with position, date, depth, heading, and pitch and roll.

The field surveys using SWaPS showed that species distributions are influenced by their respective tolerances to salinity patterns. Seagrass species with high tolerance for low salinity like *Halodule wrightii* and *Ruppia maritima* have high abundance only in areas influenced directly by canal discharges, while species with limited tolerance for low salinity like marine sponges are rare along nearshore habitats.

The use of video surveys with a high spatial precision (< 1m) provides a rapid, cost-effective, and repeatable method to monitor marine benthic communities. The most attractive features of the this system are the ability to: 1) survey large areas rapidly without the need to deploy divers; and 2) return to precise locations without the need to establish permanent markers. Moreover, the digital video and still images collected with SWaPS are a valuable permanent visual archive that can provide the baseline information needed to evaluate long-term patterns of change in environments like Biscayne Bay that are subject to increasing pressure from human activities.

ADDITIONAL INDEX WORDS

Geospatial video surveys, salinity patterns, seagrass distribution, Everglades restoration

INTRODUCTION

The hydrology of South Florida has been drastically modified in the last 50 years by the construction of a water management system comprised of an extensive network of levees, canals, water control structures, and pump stations (MCIVOR *et al*., 1994; BROWDER and OGDEN, 1999). After its construction, several adverse ecological consequences have been attributed to the changes in fresh-water delivery that have altered the natural timing, quantity, and quality of freshwater flow across the landscape. Examples of these adverse ecological changes include: 1) the mass mortality of seagrasses within Florida Bay (ZIEMAN *et al*., 1989, 1999; ROBBLEE *et al*., 1991; DURAKO, 1994), 2) significant declines in pink shrimp (*Penaeus duorarum*) catches (BROWDER, 1985; BROWDER *et al*., 1999), and 3) the mortality of marine sponges (BUTLER *et al*., 1995).

In response to these patterns of environmental decline, the recently approved, multi-billion dollar Comprehensive Everglades Restoration Plan (CERP) has been charged with the restoration, preservation, and protection of the South Florida regional ecosystem. The multiple components of this plan have been designed to restore historic hydrologic conditions and increase water storage and supply for the natural system as well as for urban and agricultural use.

One of the changes anticipated to occur with the implementation of CERP is the modification of freshwater delivery patterns (i.e., quantity, quality, timing) into the estuaries and coastal bays (DAVIS and OGDEN, 1994; STEINMAN *et al*., 2002). Significant hydrologic changes are expected primarily in nearshore habitats of Biscayne Bay and Florida Bay where increased freshwater inflows through the tidal creeks and marshes are expected to lower salinity at the point of discharge and expand areas of mesohaline conditions with unknown ecological effects on the benthic organisms found there (BROWDER and WANLESS, 2001). Considering the potential future impacts of these activities on water quality, it is crucial to establish a monitoring program to document present-day patterns in abundance, distribution, and condition of benthic communities at nearshore habitats (< 1 km from shore) likely to be affected by CERP activities. These shallow habitats (< 1 m in depth), which support healthy seagrass and hardbottom communities (LIRMAN *et al*., 2003; LIRMAN and CROPPER, 2003) and are critical nursery habitats for pink shrimp and fishes such as gray snapper and spotted seatrout (AULT *et al*., 1999a, b; DIAZ, 2001; SERAFI *et al*., 2001, 2003), have been largely neglected by existing monitoring programs, primarily due to logistic problems associated with boat access.

In this study, we describe the application of the Shallow-Water Positioning System (SWaPS), a geospatial video-based survey methodology that is well-suited to document patterns of species abundance and distribution of submerged aquatic vegetation in shallow coastal environments in a spatially accurate, rapid, and cost-effective manner. Field surveys using SWaPS were conducted along the littoral zone (< 1 m in depth) of western Biscayne Bay in 2003, providing an initial, spatially-explicit baseline database on the abundance and distribution of benthic organisms against which the effects of future watershed restoration activities may be discerned.

METHODS

Study Area

Biscayne Bay is a shallow lagoon adjacent to the city of Miami (Figure 1). The location of Biscayne Bay along a highly populated, rapidly growing urban center and just downstream of CERP activities makes this important natural resource especially vulnerable to human disturbances and changes in water quality. Salinity fields within Biscayne Bay are influenced by precipitation, freshwater inputs from land, canal and groundwater sources, and tidal influx of oceanic water. The spatial and temporal distribution of these influences delineate salinity fields with distinct characteristics. Areas with low and variable salinity are found along the western margin due to freshwater inflows from canals (12 canals discharge into Biscayne Bay), groundwater sources, and surface runoff, while higher, more stable salinities are found where oceanic influences prevail (ALLEMAN, 1995; MEEDER *et al*., 1997; , WANG *et al*., 2003) (Figure 1).

The Shallow-Water Positioning System (SWaPS)

The shallow-water positioning system (SWaPS), developed by scientists from the National Oceanographic and Atmospheric Administration's National Geodetic Survey uses a GPS receiver attached to a video camera installed in a shallow-draft boat (14-ft Carolina skiff). The GPS receiver is centered over a gimballed digital video camera that is suspended in a glass enclosure and provides a clear, down-looking view of the bottom. A fixed-position base station receiver is used to transmit real-time kinematic (RTK) data to the receiver on the survey boat by radio modem. Each video frame recorded is stamped with time, date, depth, heading, and pitch and roll (Figure 2). The time code is used to retrieve the precise location of each frame based on the location of the boat with respect to the base station.

The geospatial video surveys provide a continuous digital video track of the bottom. The data are archived by “grabbing” frames at a rate of one frame per second and storing these as digital still images. A geospatial information system (GIS) is used subsequently to link the geospatial (locations) and thematic (descriptive) data to their respective image. The raw video and the digital frames provide a permanent record that can accessed easily for future reference. In addition to the individual images, selected portions of the video can be processed to provide georefenced mosaics (Figure 3).

Spatial Precision

While high spatial precision can be achieved on land using the GPS base station and a RTK system, field conditions on the ocean (e.g., winds, currents, wave action) can often limit the ability to return to the same location. The spatial precision of SWaPS was tested using ceramic tiles deployed in the study area at a depth of 75-100 cm. The location of each tile was determined by maneuvering the boat over the tiles, capturing each one in the center of the video frame. The following day, the position of each tile was retrieved and plotted as waypoints using a GPS-navigation software. Using the GPS unit as a guide, the boat was repositioned over each waypoint. If the tile could be seen on any portion of the video screen, the tile was counted as a "hit". If the tile was not seen on the screen, the distance between the position of the boat and the position of the tile was measured to determine the extent of the "miss".

Field Surveys

In February-April of 2003, field surveys were conducted in western Biscayne Bay following the shore contour at a distance of 100-300 m at depths of 50-75 cm. While the video surveys provide a continuous data set along the survey path, a subset of stations (n = 130) were sampled at 200-300 m intervals. This approach is similar to that used by seagrass monitoring programs in the region were sites are sampled using multiple benthic quadrats (FOURQUREAN *et al.*, 2002). For each survey location (i.e., a transect < 25 m along the survey track), 5 non-overlapping frames were chosen at random from the image library. For each georeferenced digital image (i.e., the sample unit for that site), community type, species list, and abundance (percent cover) were recorded. The images were visually scored to determine the fraction of the frame that was occupied by each taxon and measurements of percent cover were averaged by site.

Because of the large influence that freshwater discharge from canals can have on the abundance and distribution of benthic organism, a detailed survey was conducted in a regular grid pattern in the vicinity of Military canal. Five roughly parallel survey tracks were followed in the area adjacent to the canal and 12 stations were sampled along each track as described. The cover data obtained for each site were used to develop percent cover contours for seagrasses and macroalgae using ArcView's Spatial using an Inverse Distance Weighted interpolation procedure.

RESULTS

Field tests showed that SWaPS can provide sub-meter precision consistently in shallow coastal areas. Out of the 30 tiles deployed, 24 (80%) were relocated within the video frame using the position obtained by post-processing the GPS information recorded during deployment. With a field of view at the bottom of approximately 60 cm, the spatial precision for the relocation of these tiles was < 50 cm . For the tiles that were not relocated within the video screen (20%), the mean distance to the center of the frame was 75 cm (S.D. = ± 12).

The skiff used by SWaPS performed well in the shallow environment of western Biscayne Bay and approximately 35 km of littoral habitats (< 75 cm in depth) were easily surveyed. Three main community types were documented in these surveys: 1) seagrass communities composed of four seagrass species (*Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Ruppia maritima*), 2) macroalgal communities with both attached and drift components, and 3) hardbottom communities composed of sponges, soft corals, and hard corals (Figure 2). While these were the three main categories, mixed benthic communities composed of organisms from two or more of these broad categories were commonly observed.

The most abundant seagrass species, *T. testudinum* was found throughout the study area, even in areas influenced by canal inflows. In contrast, *H. wrightii*, *S. filiforme*, and *R. maritima*, had lower overall abundance and highly restricted spatial distribution (Figure 1; Table 1). *S. filiforme* was restricted to the northern section of the survey area, while *R. maritima* was restricted to the southern section in areas heavily influenced by freshwater inflows from canals. The highest abundance of this species was documented in the vicinity of Black Point and Military canals. While the distribution of *H. wrightii* was also associated with areas of high freshwater inflows, this species was found throughout the study area.

Attached and drift macroalgae are also important components of the benthic communities of western Biscayne Bay and can be found throughout the area. The main components of the attached macroalgal group include *Halimeda* spp., *Caulerpa* spp., *Penicillus* spp., and *Acetabularia* sp., while *Laurencia* spp., *Chondria spp.*, and *Dictyota* spp. were the most abundant components of the drift macroalgal group. Finally, sponge-dominated hardbottom communities were only found at two sites in the northern sector of the study area (Figure 1).

Three seagrass species were found in the vicinity of Military canal, *T. testudinum*, *H. wrightii*, and *R. maritima*. The benthic habitat in the immediate vicinity of the canal discharge site is dominated by *H. wrightii* and mats of the drift alga *Laurencia*. *T. testudinum* is nearly absent or present at low abundance in this area but increases in abundance with increasing distance from the area of freshwater input (Figure 4).

Only a small number of sites in western Biscayne Bay are completely devoid of submerged aquatic vegetation. In fact only 2% of sites had no seagrass biomass present and 10% of sites had no macroalgae (drift or attached forms) biomass present (Table 1).

DISCUSSION

The SWaPS system has shown to be well-suited for monitoring benthic communities in shallow coastal environments. The abundance and distribution patterns recorded with SWaPS in the littoral zone of Biscayne Bay are consistent with previous reports that showed that the large-scale abundance, diversity, and spatial distribution of benthic organisms can be influenced by salinity regimes. The restricted distribution of *Halodule wrightii* and *Ruppia maritima*, limited to areas of freshwater discharge, correspond well with their reported tolerance for low and variable salinity (MCMAHAN, 1968; MCMILLAN, 1974; BIRD *et al*., 1993; LIRMAN and

CROPPER, 2003). In fact, *H. wrightii* was the only species found at the mouth of Military canal, which can be attributed to its life history characteristics. *H. wrightii* is commonly regarded as an early succesional species able to survive where other seagrass species would be removed by disturbance, and remain dominant under fluctuating conditions (MONTAGUE and LEY, 1993; FOURQUREAN *et al*., 1995). *R maritima* is another species with a high tolerance to low salinity (KANTRUD, 1991) that had a distribution limited to areas with high canal discharge. The distribution of *S. filiforme*, restricted to the northern portion of the study area, is also consistent with studies that suggest that this species can sustain high productivity in well-flushed areas were oceanic influences prevail (ZIEMAN *et al*., 1999; FOURQUREAN *et al*., 2002).

While *T. testudinum* is found throughout Biscayne Bay (LIRMAN and CROPPER, 2003), the distribution and abundance of this species can be influenced locally by salinity patterns. Meeder *et al*. (1997) measured maximum groundwater seepage in Biscayne Bay at about 200 m from shore, and documented a negative relationship between groundwater influence and abundance of *T. testudinum*. This relationship between *Thalassia* distribution and freshwater input was documented during our detailed surveys in the area of Military canal where this species was absent at the canal mouth but increased in abundance with increasing distance from shore.

Biber *et al*. (2004) reported that the distribution of different macroalgal groups may be influenced by salinity patterns as drift macroalgae were shown to be more tolerant of low salinity than attached macroalgae and are expected to be have. While no clear large-scale patterns in algal distribution were observed in this study with respect to the location of canals, drift macroalgae were more abundant in the immediate vicinity of Military canal while attached macroalgae were only found further away from this area. Nevertheless, macroalgal community dynamics are highly seasonal within Biscayne Bay (BIBER, 2002) and multiple surveys would be required to fully capture distribution patterns of this group in relation to physical factors.

A surprising result of our video surveys of nearshore environments of western Biscayne Bay, which experiences wide fluctuations in salinity, is that only a small number of sites were completely devoid of submerged aquatic vegetation. Moreover, sites devoid of SAV were only found at the mouths of canals, suggesting that the detrimental impacts of point discharges of freshwater are spatially restricted and highly species-specific. The highly localized impacts of freshwater discharge were also documented by Brooke (1982) who documented a sharp decline in abundance and a shift in species composition of the invertebrate faunal community at the mouth of a canal in western Biscayne Bay. Finally, the low abundance and highly restricted distribution of sponges is consistent with the reportedly low tolerance of this marine sponges to low and variable salinity (STORR, 1976; KNIGHT and FELL, 1987; CROPPER *et al*., 2001).

While salinity patterns are known to influence the abundance and distribution of benthic organisms in shallow marine habitats, there are other factors such as hydrodynamic regime, substrate characteristics, light, temperature, grazing, nutrients, and competition that also influence recruitment, growth, and survivorship patterns and need to be considered to fully understand the distribution patterns of benthic organisms (FOURQUREAN *et al*., 2003). The repeatability of the SWaPS surveys, if conducted in conjunction with a water quality monitoring program, provide a unique opportunity to evaluate the direct influence of these factors on benthic community composition.

SWaPS surveys can also be used effectively to document damage and recovery patterns in shallow habitats. One of the main sources of disturbance for seagrass and hardbottom communities in Biscayne Bay is the physical damage caused by boat groundings, boat propellers, and shrimp-trawling activities (SARGENT *et al*., 1995; AULT *et al*., 1997). With the aid of SWaPS, individual seagrass scars can be identified unequivocally and both the area damaged and the rate of scar closure rates can be quantified directly from the video frames taking into account the depth and camera/lens information (Figure 3). Similarly, the damage caused by roller-frame trawls can be assessed and the removal of organisms like sponges and soft corals can be documented if surveys are conducted prior and after these activities.

CONCLUSIONS

The use of video surveys with accurate spatial stamps provides a rapid and cost-effective method to document the abundance and distribution of benthic organisms in shallow coastal habitats without the need to deploy trained divers. Moreover, the spatial precision of this system (< 1 m) allows for locations to be monitored over time without the need to establish permanent markers. Finally, the digital video and still images collected are a valuable permanent visual archive that can provide the baseline information needed to evaluate long-term patterns of change in environments like Biscayne Bay that are subject to increasing pressure from human activities.

ACKNOWLEDGEMENTS

This research was funded by NOAA's National Geodetic Survey and the US Department of the Interior's Critical Ecosystem Studies Initiative (Award #Q528404CESI). Field support was provided by Richard Curry, Science Director of Biscayne National Park. Research activities were conducted under permit BISC-2002-SCI-0052.

LITERATURE CITED

ALLEMAN, R.W., 1995. An update to the surface water improvement and management plan for Biscayne Bay. *South Florida Water Management District,* West Palm Beach, Florida.

AULT, J.S.; SERAFY, J.E.; DIRESTA, D., and DANDELSKI, J., 1997. Impacts of commercial fishing on key habitats within Biscayne National Park. *Biscayne National Park Report*, Homestead, Florida. 80 p.

AULT, J.; DIAZ, G.A.; SMITH, S.G.; LUO, J., and SERAFY, J.E., 1999a. A spatial dynamic multistock production model. *North American Journal of Fisheries Management*, 19, 696-712.

AULT, J., LUO, J.; SMITH, S.G.; SERAFY, J. E.; WANG, J.D.; HUMSTON, R., and DIAZ, G.A., 1999b. A spatial dynamic mulstistock production model. *Canadian Journal of Fisheries and Aquatic Science*, 56, 4-25.

BIBER, P.D., 2002. The Effects of Environmental Stressors on the Dynamics of Three Functional Groups of Algae in *Thalassia testudinum* habitats of Biscayne Bay, Florida: A Modeling Approach. Miami, Florida: Ph.D. Dissertation, University of Miami, 367 p.

BIBER, P.D.; HARWELL, M.A., and CROPPER Jr., W.P., 2004. Modeling the dynamics of three functional groups of macroalgae in tropical seagrass habitats. *Ecological Modelling*, 175, 25-54.

BIRD, K.T.; CODY, B.R.; JEWETT-SMITH, J., and KANE, M.E., 1993. Salinity effects on *Ruppia maritima* L. cultured in vitro. *Botanica Marina*, 36, 23–28.

BROWDER, J. A., 1985. Relationship between pink shrimp production on the Tortugas Grounds and water flow patterns in the Florida Everglades. *Bulletin of Marine Science*, 37, 839-856.

BROWDER, J. A., and OGDEN, J. C., 1999. The natural South Florida system II: predrainage ecology. *Urban Ecosystems*, 3, 245-277.

BROWDER, J. A.; RESTREPO, V.R.; RICE, J.K.; ROBBLEE, M.B., and ZEIN-ELDIN, Z., 1999. Environmental Influences on Potential Recruitment of Pink Shrimp, *Farfantepenaeus duorarum*, from Florida Bay Nursery Grounds. *Estuaries*, 22, 484-499.

BROWDER, J. A., and WANLESS, H. R., 2001. *Biscayne Bay Partnership Initiative. Survey Team Final Reports.* Miami, Florida. pp. 65-230.

BUTLER IV, M.J.; HUNT, J.H.; HERRNKIND, W.F.; CHILDRESS, M.J.; BERTELSEN, R.; SHARP, W.; MATTHEWS, T.; FIELD, J.M., and MARSHALL, H.G., 1995. Cascading disturbances in Florida Bay, USA: Cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters *Panulirus argus*. *Marine Ecology Progress Series*, 129, 119-125.

CROPPER JR, W. P.; LIRMAN, D.; TOSINI, S. C.; DIRESTA, D.; LUO, J., and WANG, J., 2001. Sponge population dynamics in Biscayne Bay, Florida. *Estuarine Coastal and Shelf Science*, 53, 13-23.

DAVIS, S. M., and OGDEN, J. C., 1994. Toward Ecosystem Restoration. *In*: Davis, S. M. and Ogden, J. C. (eds.), *Everglades. The Ecosystem and its Restoration*. St. Lucie Press, Delray Beach, Florida. pp. 769-797

DIAZ, G.A., 2001. Population dynamics and assessment of pink shrimp (*Farfantepenaeus duorarum*) in subtropical nursery grounds. Miami, Florida: Ph.D. Dissertation, University of Miami, 175 p.

DURAKO, M. J., 1994. Seagrass die-off in Florida Bay (USA): changes in shoot demographic characteristics and population dynamics in *Thalassia testudinum*. *Marine Ecology Progress Series*, 110, 59-66.

FOURQUREAN, J. W.; POWELL, G. V. N.; KENWORTHY, W. J., and ZIEMAN, J. W., 1995. The effects of long-term manipulation of nutrient supply on competition between the seagrasses *Thalassia testudinum* and *Halodule wrightii* in Florida Bay. *Oikos*, 72, 349-358.

FOURQUREAN, J. W., DURAKO, M. J.; HALL, M. O., and HEFTY, L. N., 2002. Seagrass distribution in South Florida: a multi-agency coordinated monitoring program. *In*: Porter, J.W. and Porter, K.G. (eds.). *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Sourcebook.* CRC Press, Boca Raton, Florida. pp. 497-522.

FOURQUREAN, J.W., BOYER, J.N.; DURAKO, M.J.; HEFTY, L.N., and PETERSON, B.J., 2003. Forecasting responses of seagrass distributions to changing water quality using monitoring data. *Ecological Applications*, 13, 474-489.

KANTRUD, H.A., 1991. Wigeongrass (*Ruppia maritima* L.): A Literature Review. *Fish and Wildlife Research Report 10*, US Fish and Wildlife Servvice, 58 p.

KNIGHT, P.A., and FELL, P. E., 1987. Low salinity induces reversible tissue regression in the estuarine sponge *Micociona prolifera* (Ellis & Solander). *Journal of Experimental Marine Biology and Ecology*, 107, 253–261.

LIRMAN, D., and CROPPER JR, W.P., 2003. The influence of salinity on seagrass growth, survivorship, and distribution within Biscayne Bay, Florida: field, experimental, and modeling studies. *Estuaries*, 26, 131-141.

LIRMAN, D., ORLANDO, B.; MACIÁ, S.; MANZELLO, D.; KAUFMAN, L.; BIBER, P., and JONES, T., 2003. Coral communities of Biscayne Bay, Florida and adjacent offshore areas:

Diversity, abundance, distribution, and environmental correlates. *Aquatic Conservation,* 13, 121-135.

MCIVOR, C.C.; LEY, J.A., and BJORK, R.D., 1994. Changes in freshwater inflow from the Everglades to Florida Bay including effects on biota and biotic precesses: a review. *In*: Davis S.M.; and Ogden, J.C. (eds). *Everglades. The Ecosystem and its Restoration*. St. Lucie Press, Delray Beach, Florida. pp. 117-146.

MCMAHAN, C. A., 1968. Biomass and salinity tolerance of shoalgrass and manateegrass in Lower Laguna Madre, Texas. *Journal of Wildlife Management*, 32, 501-506.

MCMILLAN, C., 1974. Salt tolerance of mangroves and submerged aquatic plants. *In*: Reimold, R.J.; and Queen, W. H. (eds.). *Ecology of Halophytes*. Academic Press, New York. pp. 379-390.

MEEDER, J.F.; ALVALORD, J.; BYRN, M.; ROSS, M.S., and RENSHAW, A., 1997. Distribution of Benthic Nearshore Communities and Their Relationship to Ground Water Nutrient Loading. *Final Report to Biscayne National Park from the Southeast Environmental Research Program,* Florida International University, Miami, Florida.

MONTAGUE, C. L., and LEY, J. A., 1993. A possible effect of salinity fluctuation on abundance of benthic vegetation and associated fauna in Northeastern Florida Bay. *Estuaries*, 16, 703-717.

ROBBLEE, M. B., BARBER, T. R.; CARLSON, P. R.; DURAKO, M. J.; FOURQUREAN, J. W.; MUEHLSTEIN, L. K.; PORTER, D.; YARBRO, L. A.; ZIEMAN, R. T., and ZIEMAN, J. C., 1991. Mass mortality of the tropical seagrass *Thalassia testudinum* in Florida Bay (USA). *Marine Ecology Progress Series*, 71**,** 297-299.

SARGENT, F.J., LEARY, T.J., CREWZ, D.W., and KRUER, C.R., 1995. Scarring of Florida's seagrasses: assessment and management options. *FMRI technical report TR-1*. Florida Department of Environmental Protection, St. Petersburg, Florida.

SERAFY, J.E.; FAUNCE, C.H., and LORENZ, J.J., 2003. Mangrove shoreline fishes of Biscayne Bay, Florida. *Bulletin of Marine Science,* 72, 161-180.

SERAFY, J.E.; AULT, J.S.; ORTNER, P., and CURRY, R., 2001. Coupling Biscayne Bay's natural resources and fisheries to environmental quality and freshwater inflow management., *Biscayne Bay Partnership Initiative. Science Team Final Reports*. Miami, Florida. pp. 163-174.

STEINMAN, A.D.; HAVENS, K.E.; CARRICK, H.J., and VANZEE, R., 2002. The past, present, and future hydrology and ecology of Lake Okeechobee and its watersheds. *In*: Porter, J.W.; and K.G. Porter (eds.). *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Sourcebook.* CRC Press, Boca Raton, Florida. pp. 19-37.

STORR, J. F., 1976. Field observations of sponge reactions as related to their ecology. *In*: Harrison, F. W.; and Cowden, R. R. (eds.). *Aspects of Sponge Biology,* Academic Press, New York, pp. 277–282.

WANG, J. D.; LUO, J., and AULT, J., 2003. Flows, Salinity, and Some Implications on Larval Transport in South Biscayne Bay, Florida. *Bulletin of Marine Science,* 72, 695-723.

ZIEMAN, J. C.; FOURQUREAN, J. W., and IVERSON, R. L., 1989. Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. *Bulletin of Marine Science,* 44, 292-311.

ZIEMAN, J. C.; FOURQUREAN, J. W., and FRANKOVICH, T. A., 1999. Seagrass die-off in Florida Bay: long-term trends in abundance and growth of turtle grass, *Thalassia testudinum*. *Estuaries,* 22, 460-470.

FIGURE LEGENDS

Figure 1. Mean percent cover of benthic organisms in western Biscayne Bay (n = 5 frames per site). A) *Thalassia testudinum*, B) *Halodule wrightii*, C) *Syringodium filiforme*, D) *Ruppia maritima*, E) Attached macroalgae, F) Drift macroalgae, G) Sponges. The maps show the location of the water management canals in white and the location of western (⊗) and central (⊕) salinity probes used to measure salinity patterns. Salinity curves show mean salinity (psu) based on hourly observations taken in 1998.

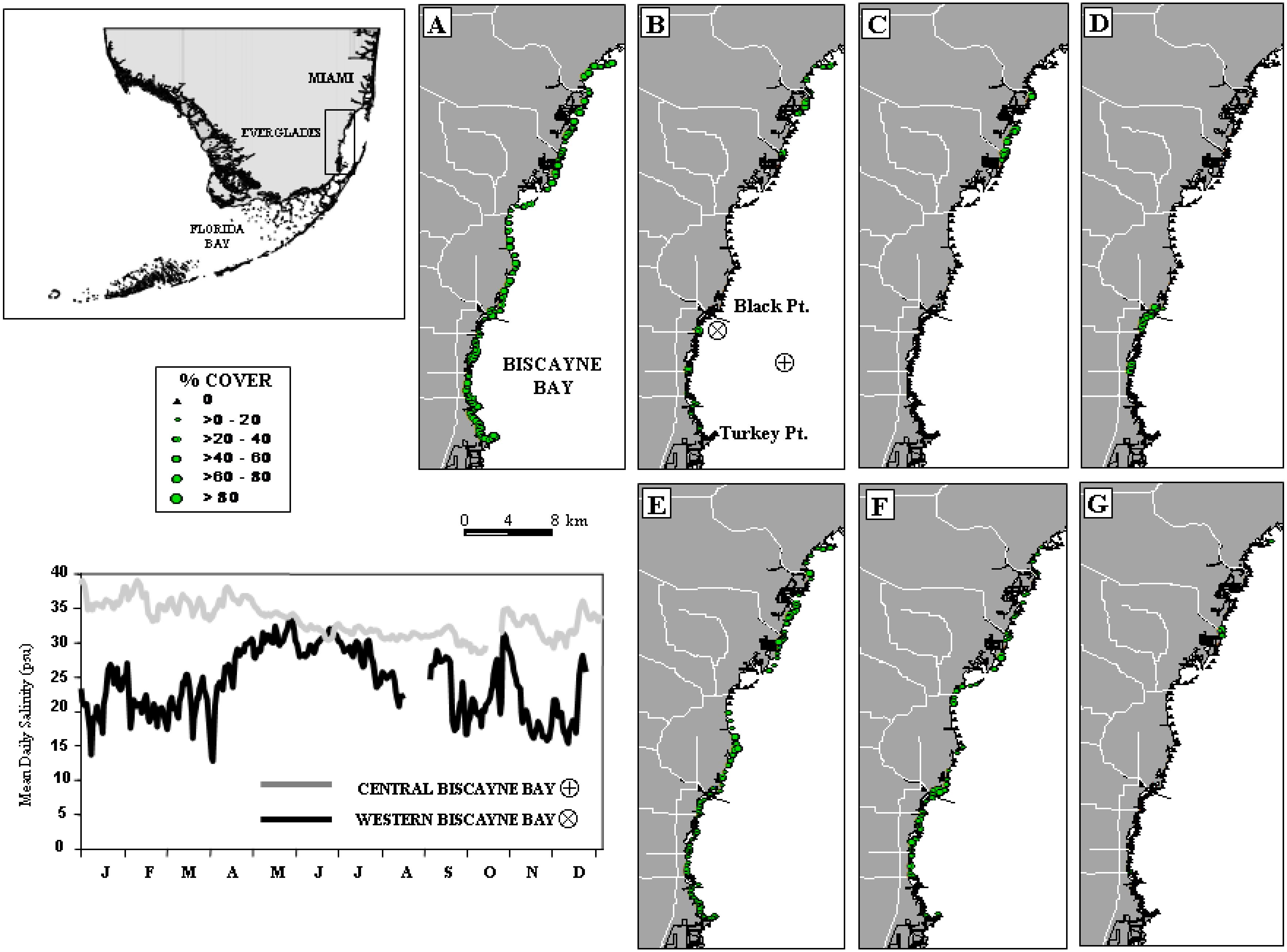
Figure 2. Representative frames from the video collected using SWaPS showing components of A) seagrass, B) macroalgal, and C) hardbottom communities of western Biscayne Bay.

Figure 3. Video mosaics of the benthos obtained from the digital video collected using SWaPS. Mosaics were created using the SnapDV software. A)*Thalassia testudinum* meadow in western Biscayne Bay, B) seagrass scar caused by a boat propeller.

Figure 4. Percent cover of submerged aquatic vegetation in the vicinity of Military Canal. Canals appear in red. Survey tracks appear in blue in panel C. Contour maps are based on mean percent cover values (n = 5 frames) obtained from 12 stations per track. Survey stations were located approximately 200 m apart. Contours were created using ArcView's Spatial Analyst. A) *Thalassia testudinum,* B) *Halodule wrightii,* C) *Syringodium filiforme,* D) *Ruppia maritima,* E) Drift macroalgae, F) Attached macroalgae.

Table 1. Abundance and distribution of submerged aquatic vegetation within nearshore habitats of western Biscayne Bay, Florida. A total of 130 stations (n = 5 frames per station) were surveyed along a continuous path at a distance of 100-300 m from shore.

	Distribution (% of sites)	Mean % Cover (± S.D.)
Thalassia testudinum	82	41.9 (38.6)
Halodule wrightii	18	6.8 (19.6)
Syringodium filiforme	9	5.2 (17.6)
Ruppia maritima	12	5.6 (17.8)
Drift macroalgae	70	14.3 (20.4)
Attached macroalgae	47	8.4 (15.9)



MIAMI
EVERGLADES
FLORIDA BAY
A
B
C
D
E
F
G
BISCAYNE BAY
Black Pt.
Turkey Pt.
% COVER
0
>0 - 20
>20 - 40
>40 - 60
>60 - 80
> 80
0 4 8 km
Mean Daily Salinity (psu)
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D
CENTRAL BISCAYNE BAY
WESTERN BISCAYNE BAY

Fig. 1

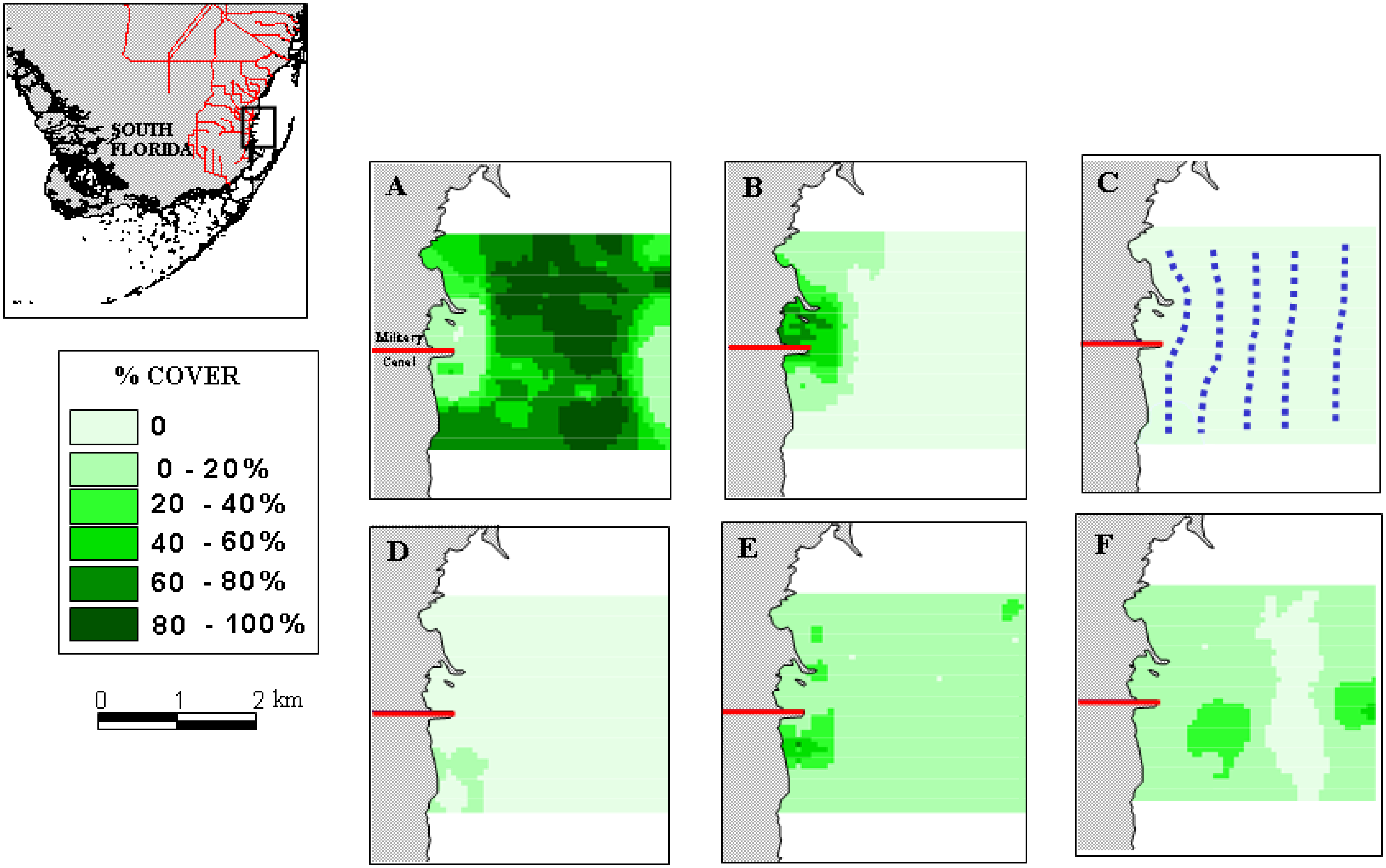

SOUTH
FLORIDA
% COVER
0
0 - 20%
20 - 40%
40 - 60%
60 - 80%
80 - 100%
0
1
2 km
A
Military
Canal
B
C
D
E
F

Fig. 4